Mars Water Mapping Projects

Background and Overview

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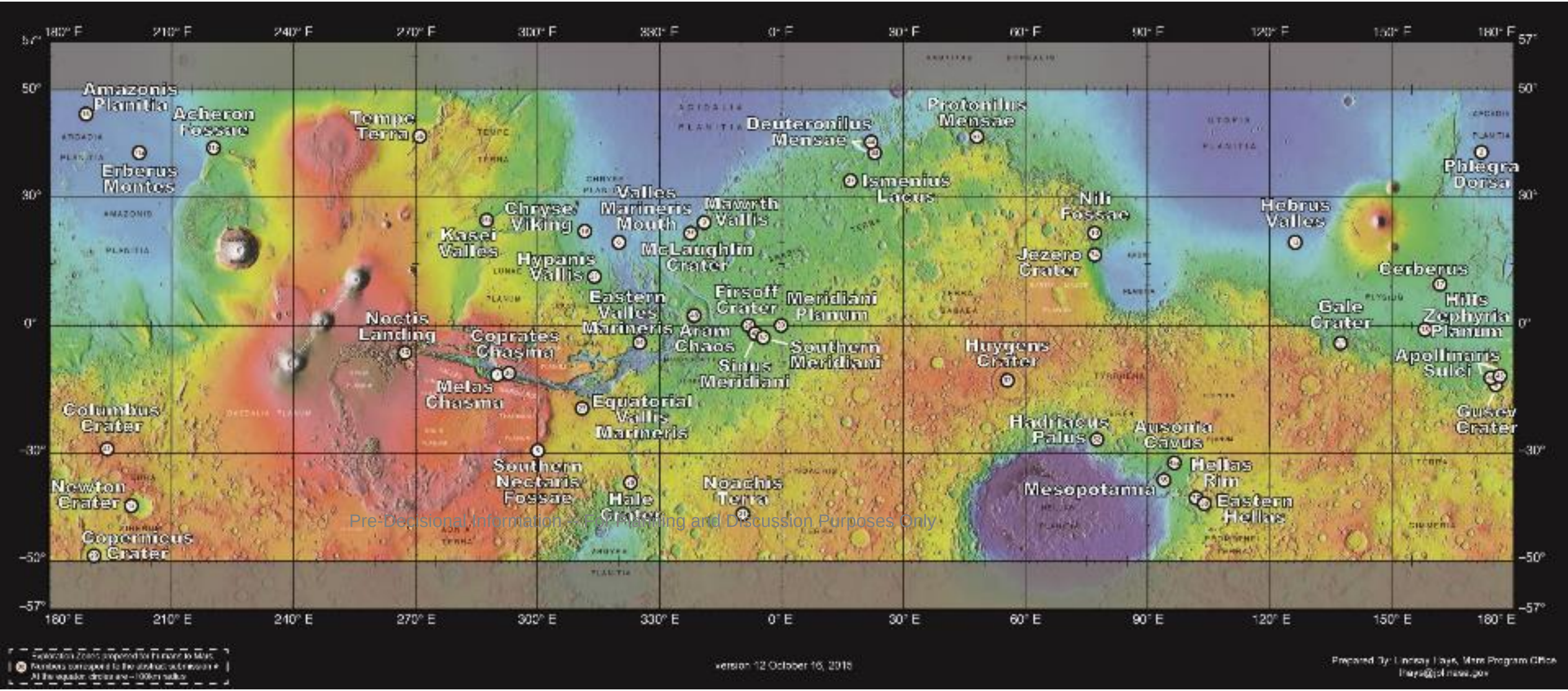
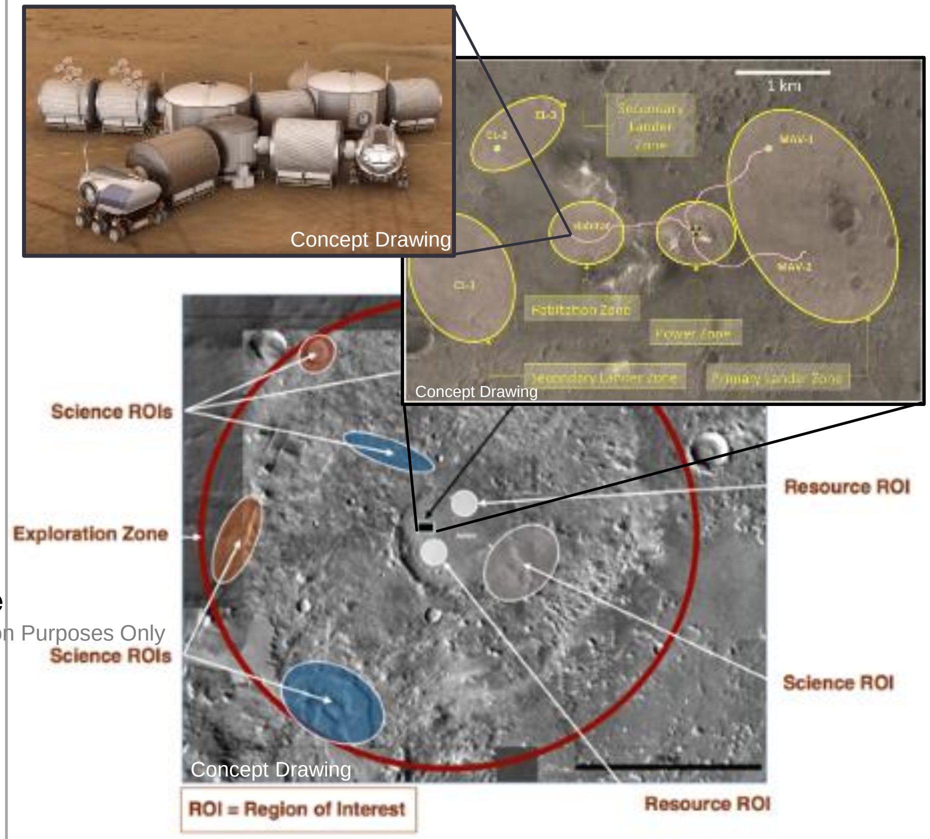
Background: Where should we land humans on Mars?



Exploration Zone (EZ) – Current Definition

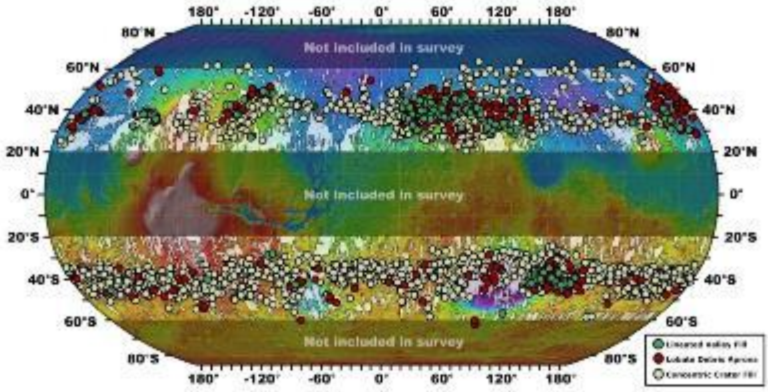
- 100km radius site at latitude band: ±50° (to be updated)

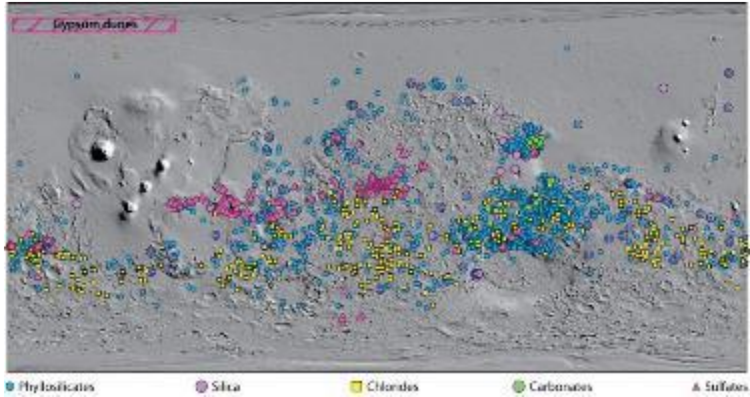
- Contains:
  - **Habitation Site**: Flat, stable terrain for emplacement of infrastructure, located ≤5km from landing site location
  - **Landing Site(s):** Flat, stable terrain, low rockiness, clear over length scales greater than landing ellipse
  - **Resource Regions of Interest**
    - One or more potential near-surface (≤3m) water resource feedstocks in a form that is minable by highly automated systems, and located within ~1-3km of ISRU processing and power infrastructure. Total extractable water should be ~100MT (supports ~5 missions)
    - Show potential for minable metal/silicon resources, mainly Fe, Al, and Si, located within ~1-2m of the surface
  - **Science Regions of Interest**
    - That address MEPAG goals (i.e. Astrobiology, Atmospheric Science, and Geoscience)



Mars Water Mapping Projects

- Ongoing projects to create the best possible maps of water distribution by combining currently available orbiter data
- Two types of mapping projects identified as highest priority:
  - **Task A – Subsurface Ice Map** (Proof of Concept)
    - *Within a single 5-10° wide longitudinal swath from 0°-60°N latitude, generate a map that identifies potential locations of subsurface water ice at low- to mid-latitudes and characterizes the nature of the gradational boundary from regions of continuous ice to discontinuous ice, through to regions of no ice.*
  - **Task B – Hydrated Minerals (Global Map)**
    - *Develop algorithms to partially automate the processing of spectra of hydrated mineral detections. Use developed algorithms to generate global map of all existing near-surface hydrated mineral detections*
- Maps expected mid-2019





Mars Water Mapping Teams

	Task A – Subsurface Ice Mapping	Task B – Hydrated Minerals Mapping
Team 1	Putzig et al. (PSI) *Mapping Buried Water Ice in Arcadia & Beyond with Radar & Thermal Data*	Carter et al. (Paris-Sud Univ.) *A Global Aqueous Mineral Abundance Catalog for Mars*
Team 2	Morgan et al. (PSI) *Local Subsurface Ice Mapping Through the Integration of SHARAD Derived Data Products with Other Datasets*	Seelos et al. (APL) *CRISM-Derived Global Map of Hydrated Mineral Bearing Units*

Merged and Expanded to Map the Northern Hemisphere – August 2018

Subsurface Water Ice Mapping (SWIM) in the Northern Hemisphere of Mars

2019 March 6

Overview for Human Landing Sites Study Google Hangout

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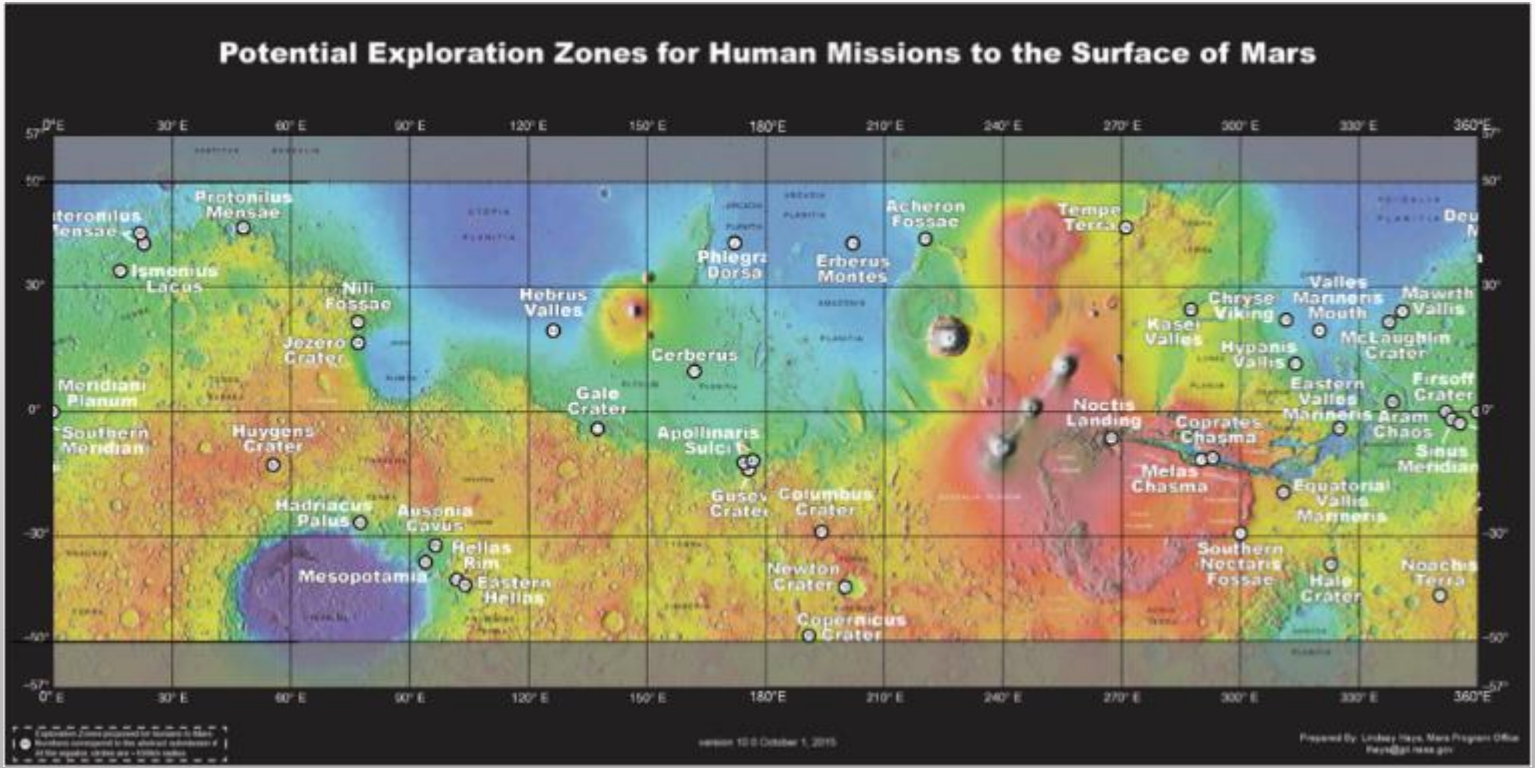
[a] Planetary Science Institute, [b] Smithsonian Institution, [c] Consultant, [d] NASA Goddard Space Flight Center, [e] Southwest Research Institute, [f] University of Arizona, [g] USGS-Flagstaff

Outline

1. Prior State of Knowledge
2. Methods
3. Arcadia Planitia Results
4. Expanded Study Plans



Human Landing Site Selection Workshop (2015)

Prior detection of shallow (<1 m) water ice

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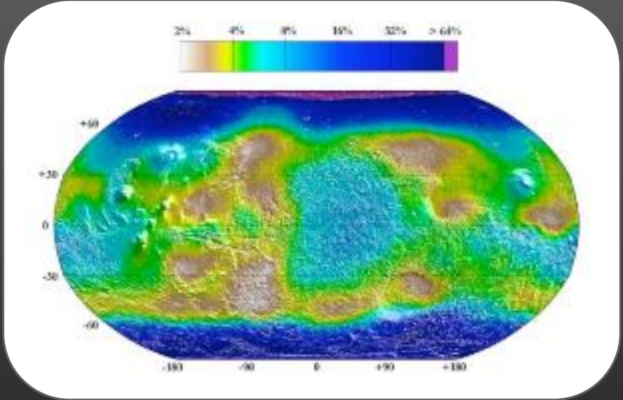
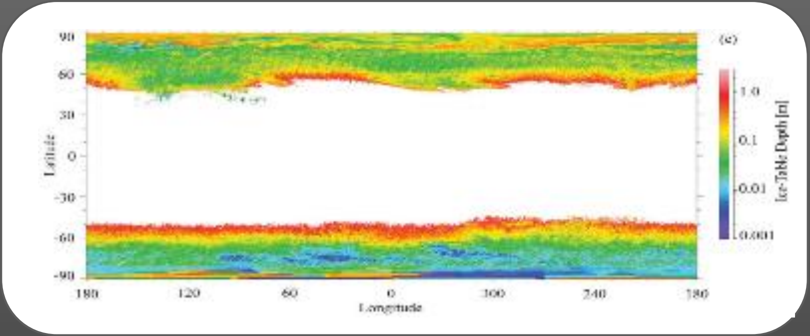
- Theory + Thermal Data = ice is likely present all across the **high (>50°) latitudes of Mars.**

Water-equivalent hydrogen content [Feldman et al., 2004].

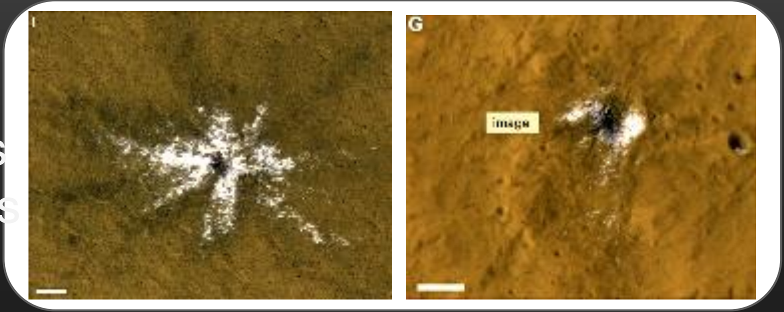




TES derived Depth of the ice table [Mellon et al., 2004].

- Neutron Spectrometer mapped water ice **in these same regions.**

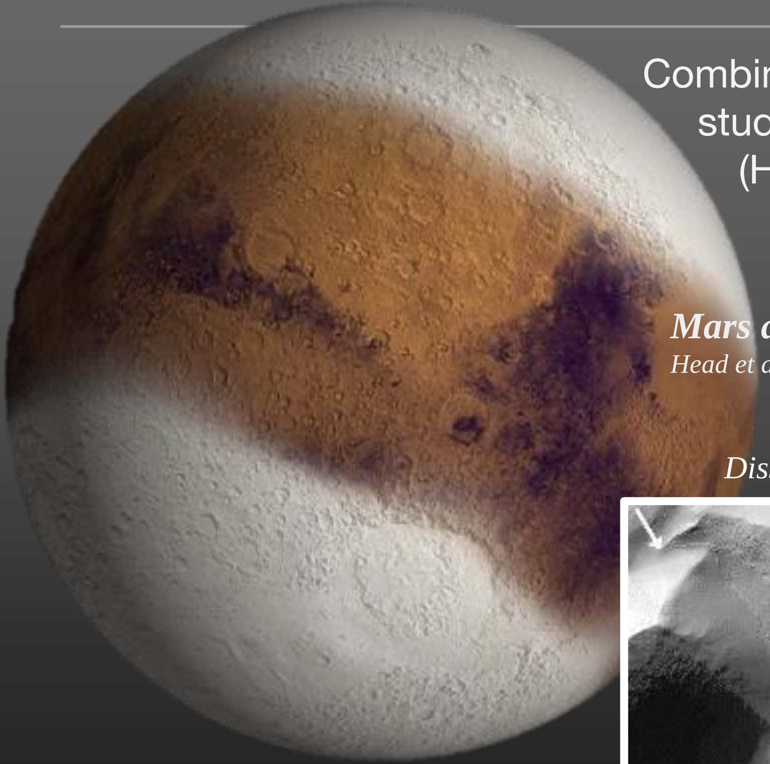
- Fresh ice-exposing small impact craters provide direct evidence of shallow ice as far **south at 39 °N**



HiRISE images [Byrne et al., 2009; Dundas et al., 2013]

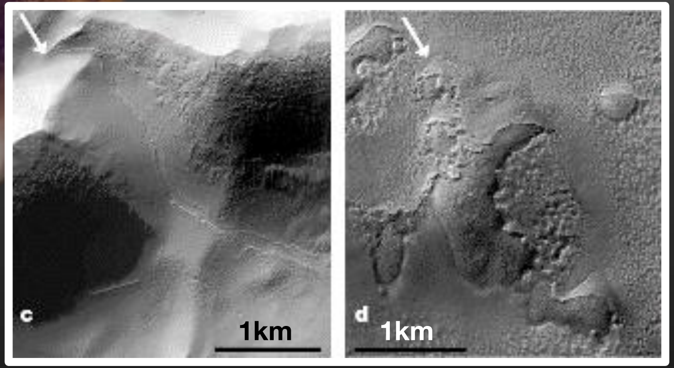
Prior detection of ice: Morphology Studies

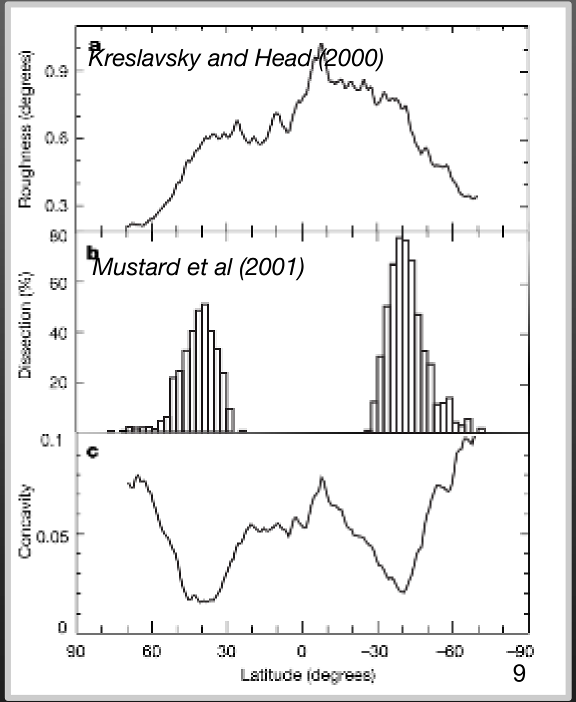
Combination of high resolution image (MOC) and surface roughness studies (MOLA) led to the Mars **Ice Age Hypothesis** (Head et al., 2003).



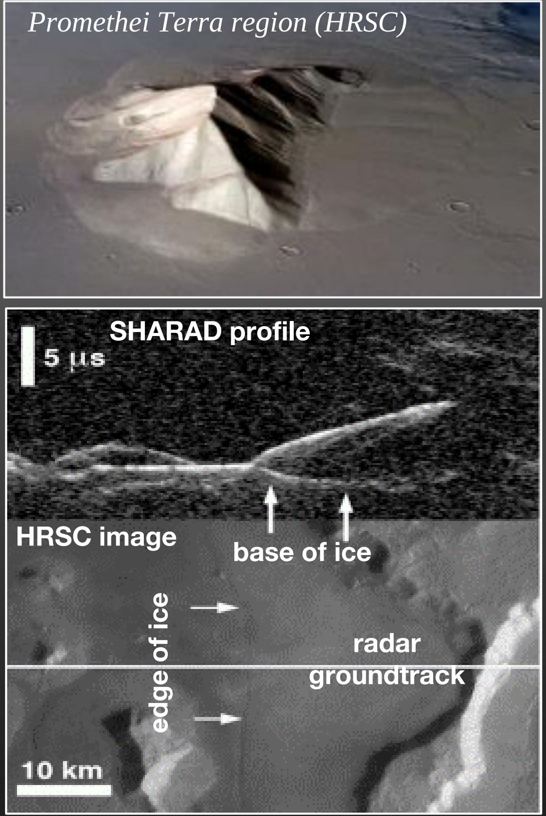
Mars at low obliquity?
Head et al (2003)

Dissected Mantle at mid-latitudes



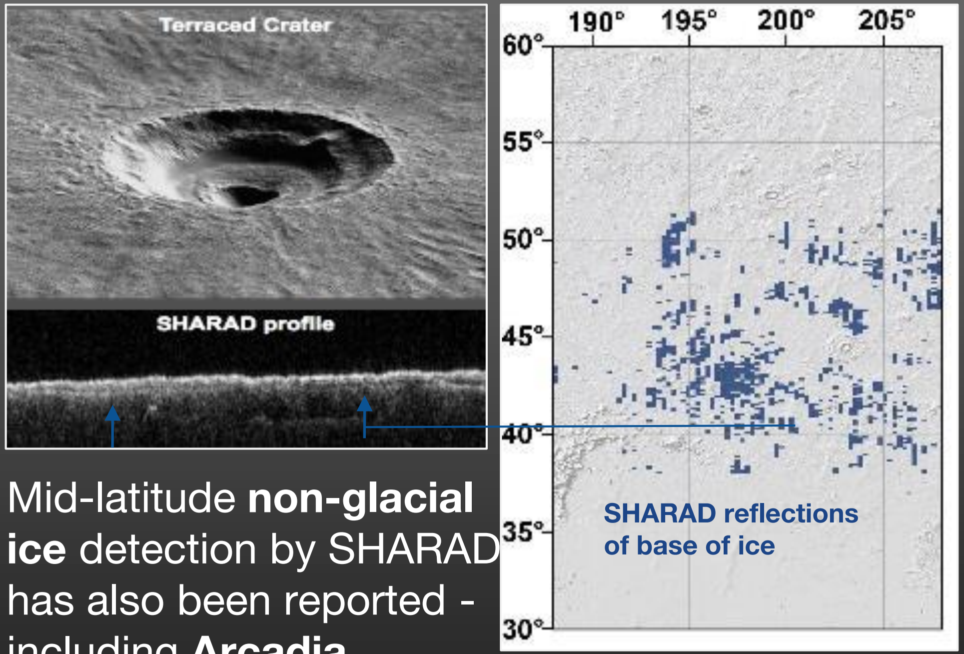


Prior detection of deep (>20 m) water ice



Shallow Radar (SHARAD) has shown that some of the **glacial features** are **nearly pure water ice**.

[Plaut et al., 2009].



Mid-latitude **non-glacial ice** detection by SHARAD has also been reported - including **Arcadia**

[Bramson et al., 2015].

Ice stability zones and prior detections

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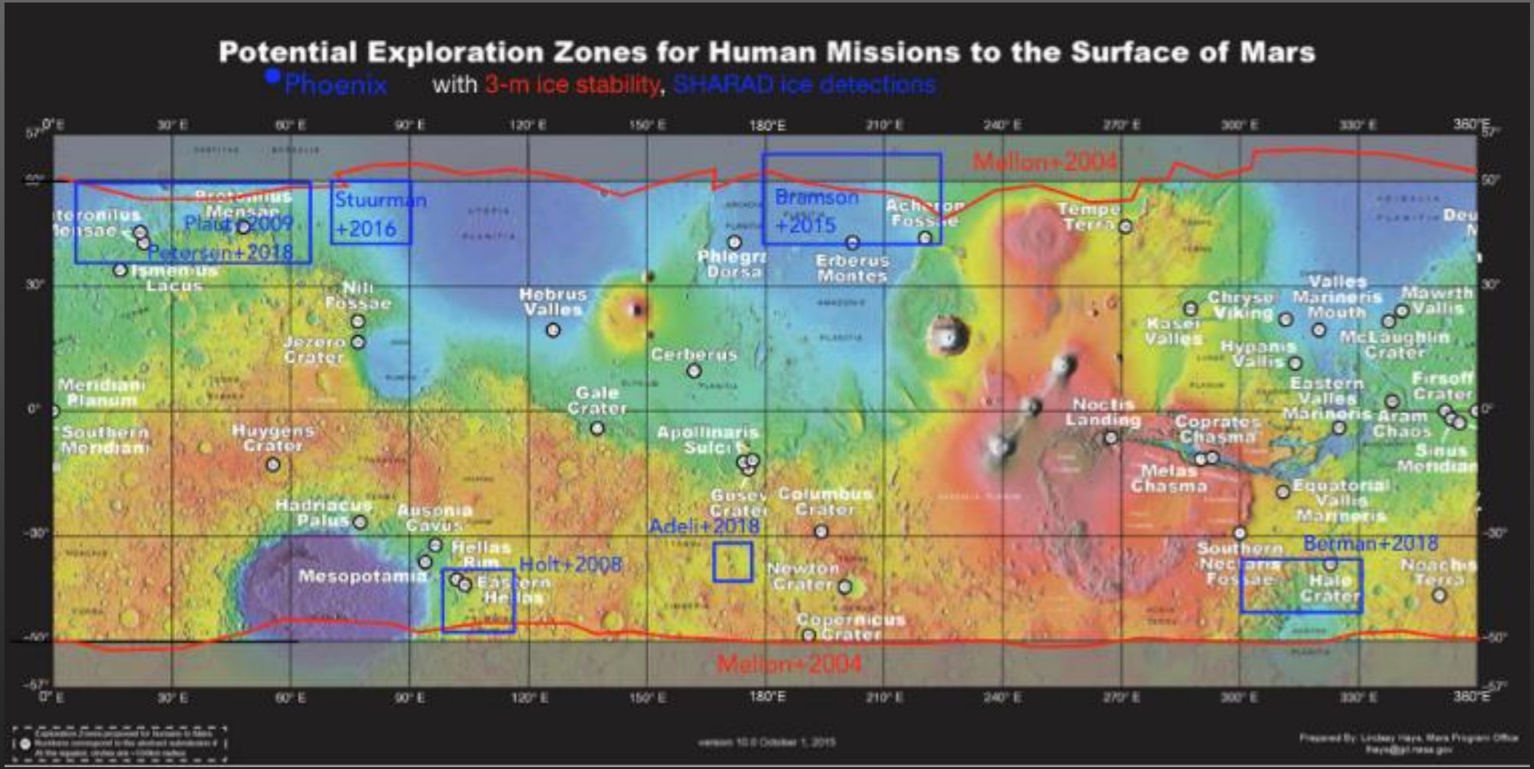
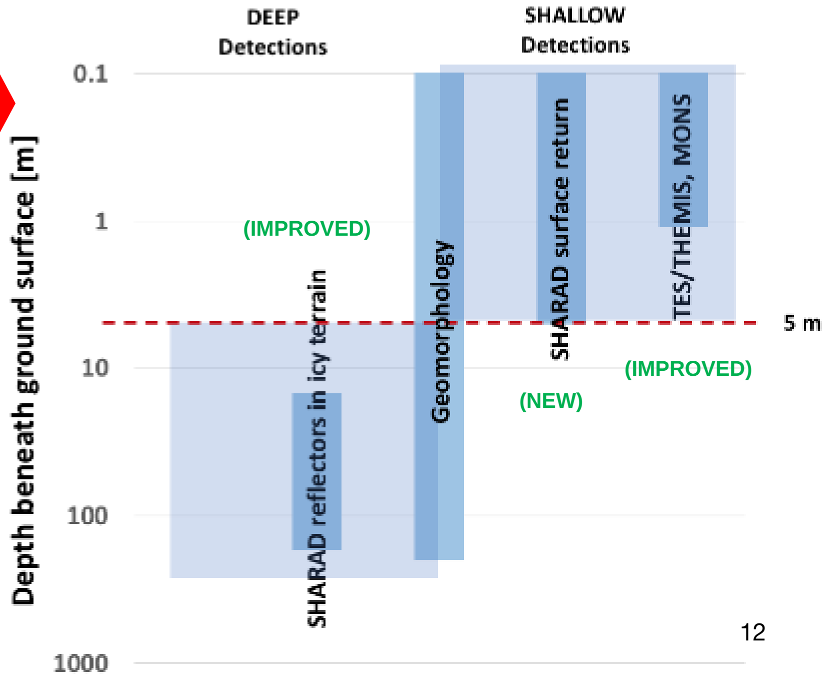


Human Landing Site Selection Workshop (2015)

SWIM Approach to Mapping Ice

- Previous Martian subsurface ice studies used datasets in **isolation** or combined techniques in **limited geographical areas.**

- For this study, we ***combine previous methods with newly developed techniques*** to probe the subsurface for water ice. New techniques include:
  - Measuring ***SHARAD surface power return*** to infer presence of ice within the top 5 m.
  - State-of-the-art ***super-resolution processing techniques*** that increase data resolution, potentially resolving top of ice.
  - The ***"split-chirp" technique***, sub-band processing to measure ***material loss properties*** - thereby constraining bulk composition.



SWIM Pilot Study Swaths

and theoretical ice-stability limits + SHARAD ice detections

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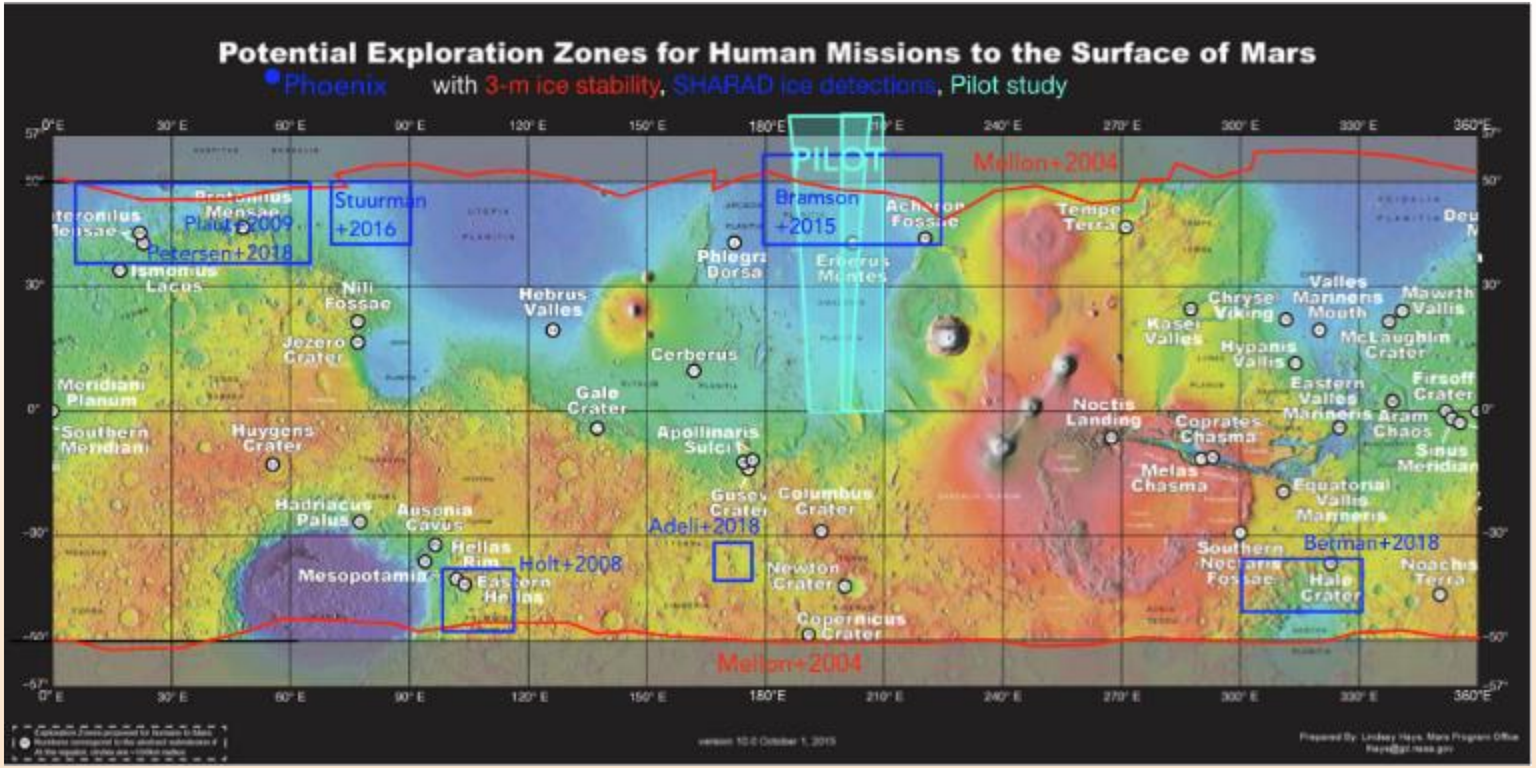
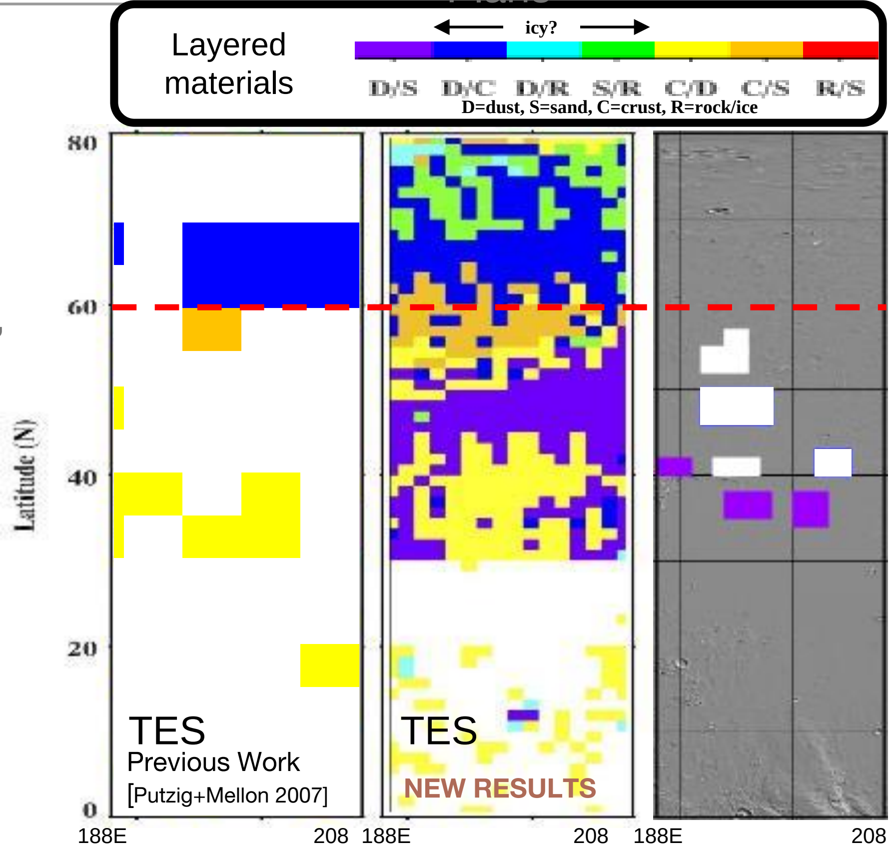


Human Landing Site Selection Workshop (2015)

Thermal Analysis

TES: MGS Thermal Emission Spectrometer
THEMIS: ODY Thermal Imaging System

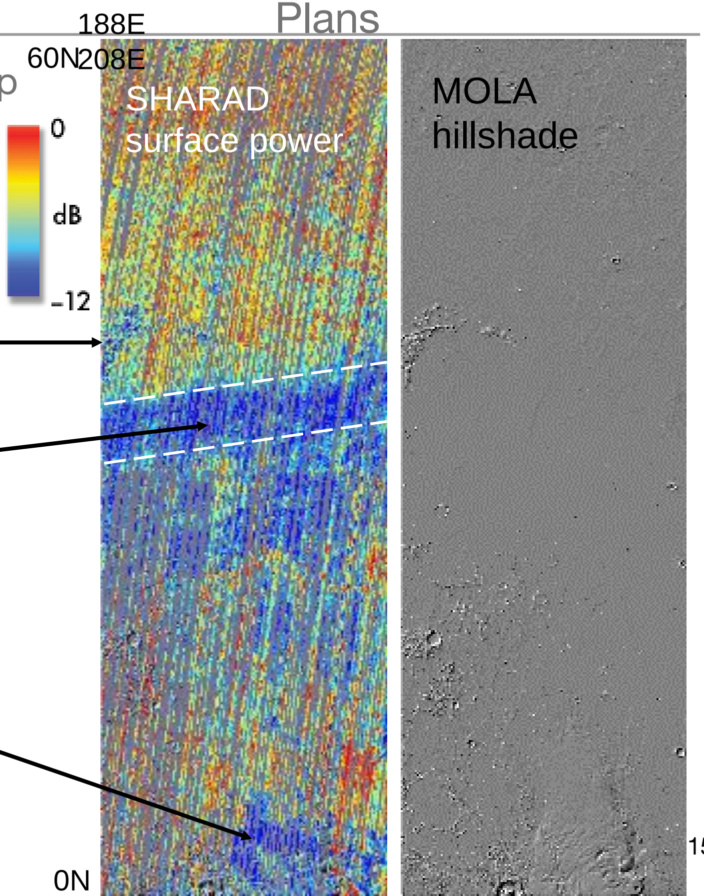
- Apparent thermal inertia (ATI) varies seasonally at locations where the subsurface is heterogeneous within ~1 m depth [Putzig & Mellon 2007].
- Comparing observed and modeled ATI, we find locations of layering consistent with shallow ice, some patches now found southward to ~30°N.
- **SWIM TES:** improved resolution by factor of 4 and greatly infilled layer-matching coverage.
- **SWIM THEMIS:** seasonal nighttime images, focused on areas of interest (sparse in Arcadia).
- **TES/THEMIS differences:**
  - THEMIS uses nighttime data only
  - TES uses day & night model match



SHARAD Surface Reflection Mapping

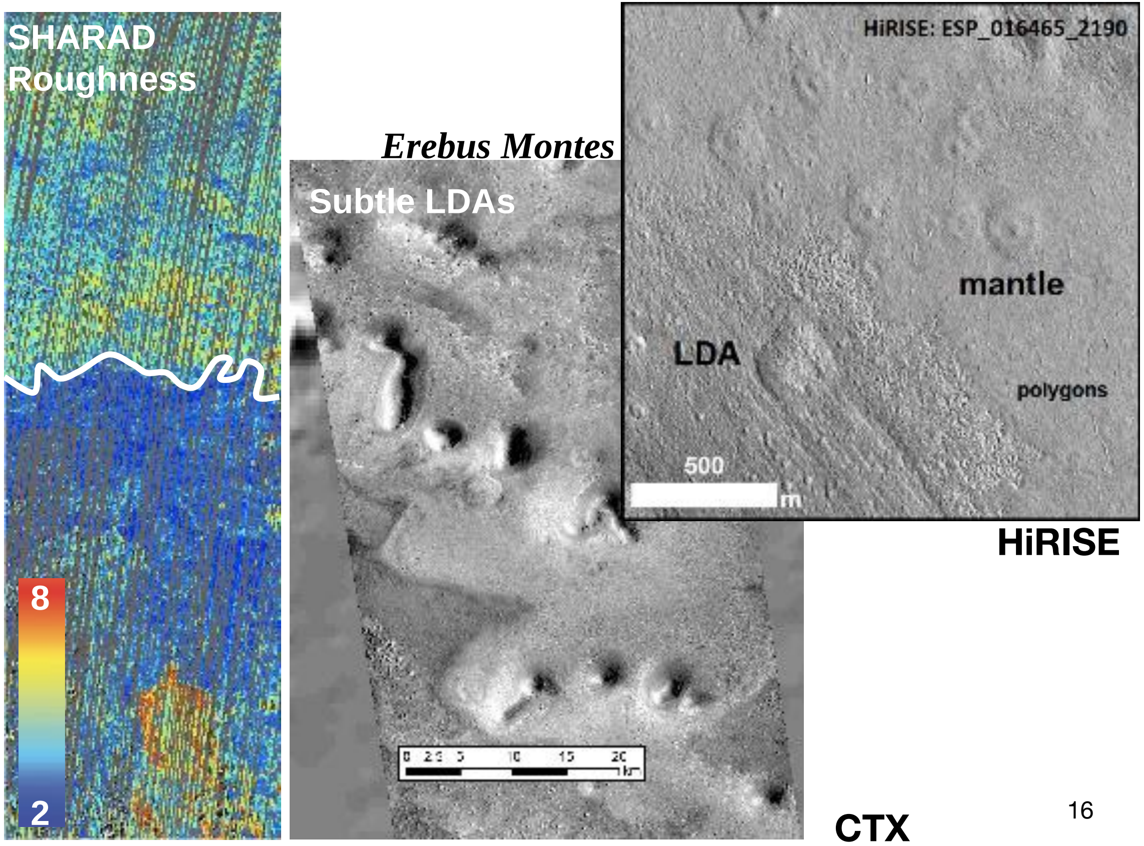
New Technique corrects the SHARAD surface reflection to map density variations in the upper 5 m.
Low power = low density materials/**ice.**
High power = High density/rock

- In northern Arcadia Planitia, we find isolated, low-power areas, e.g. within the **Erebus Montes glacial features.**
- An extensive belt of low-power returns (indicative of low-density materials) correlates with **regions of known dust upwelling in northern Amazonis.**
- The **Medusae Fossae Formation** exhibits low power, consistent with prior estimates of low dielectric permittivity [Waters et al. 2007; Carter et al. 2009; Morgan et al. 2015].



Geomorphology

- Geomorphology bridges the gap between shallow and deep data sets.
- We investigate shallow ice by mapping landforms interpreted to be ice-rich such as **patterned ground**, **scalloped pits** and **mantling units**.
- Mapping is conducted using image data such as **CTX** and **HiRISE.**
- We also use **SHARAD roughness** (10-100 m horizontal baseline) to trace the boundary of dissected mantle and no mantle (white line at right).

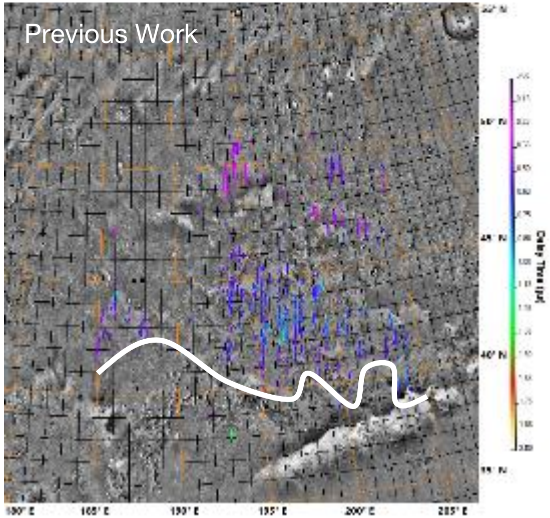


SHARAD Subsurface Reflector Mapping

- We extended reflector mapping of Bramson et al. [2015], including southward extension to ~ 35.6°N.
- Using 23 topographic features, we find real dielectric permittivity between 3 and 6, with a median of 5, above the shallow reflector.
- Our revised permittivity allows a large fraction of non-ice material* without ruling out ice presence.

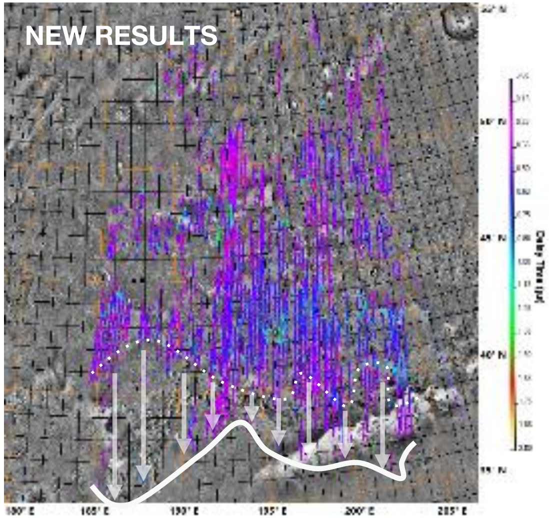
* See also Campbell & Morgan [2018].

Previous state-of-the-art mapping in Arcadia Planitia [Bramson et al. 2015]:



This work:

- ***Increased coverage***
- ***Refined dielectric constants (material composition)***
- ***More-equatorward detections***



Composite Ice Consistency

We introduce **the SWIM Equation**, in the spirit of the famous Drake Equation:

$C_I = (C_N + C_T + C_G + C_{RS} + C_{RD}) \div 5$ Consistency of data with the presence of buried ice

We map **consistency values** for each dataset:

C_N Consistency of neutron-detected hydrogen with shallow (< 1 m) ice

C_T Consistency of thermal behavior with shallow (< 1 m) ice

C_G Consistency of geomorphology with shallow and deep ice

C_{RS} Consistency of radar surface echoes with shallow (< 5 m) ice

C_{RD} Consistency of radar dielectric properties with deep (> 5 m) ice

Consistency: Arcadia Planitia

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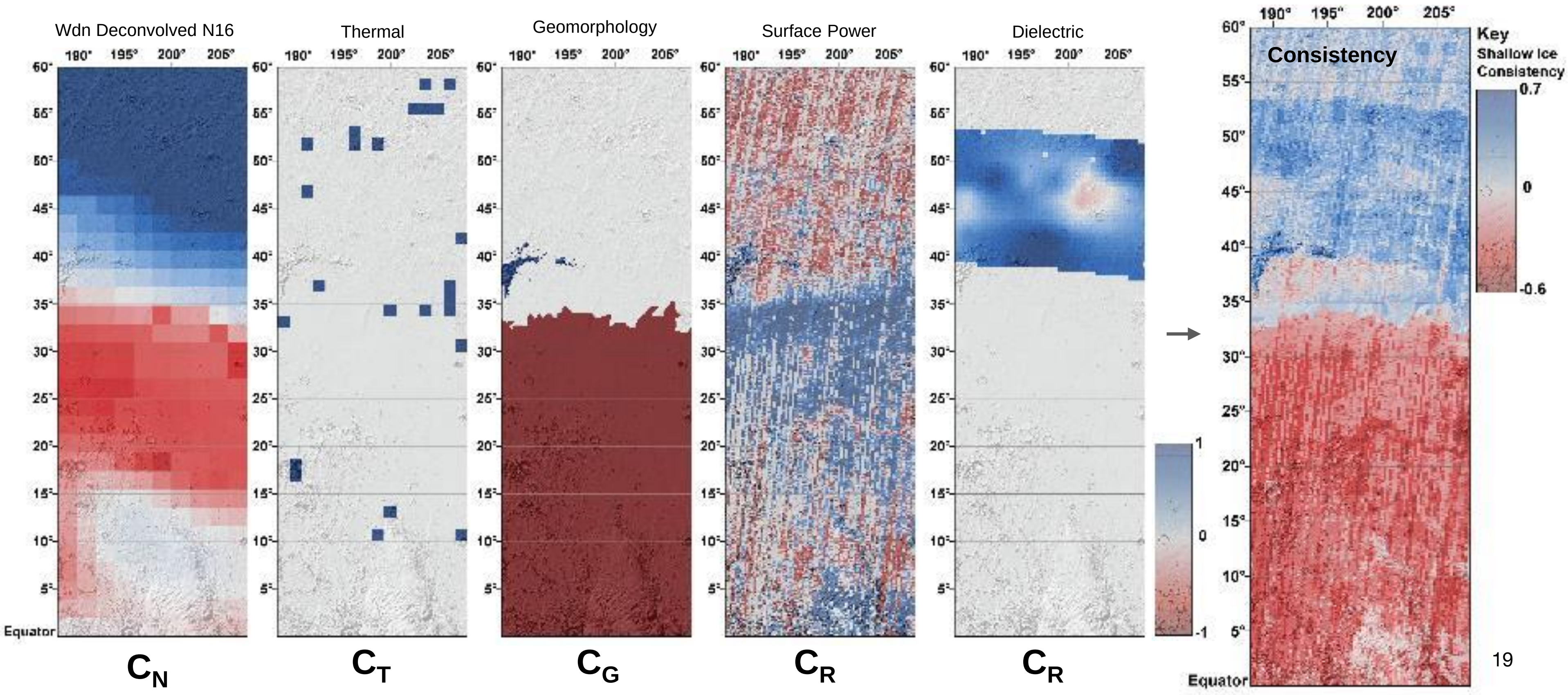

Consistency:
Integrating shallow + Deep

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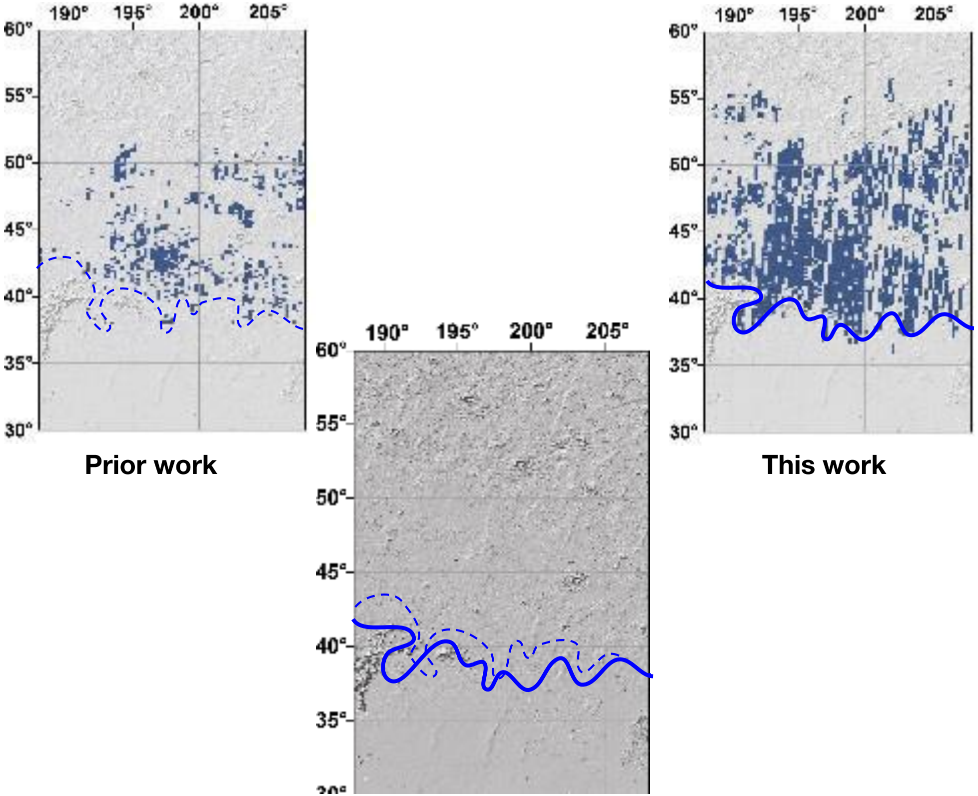
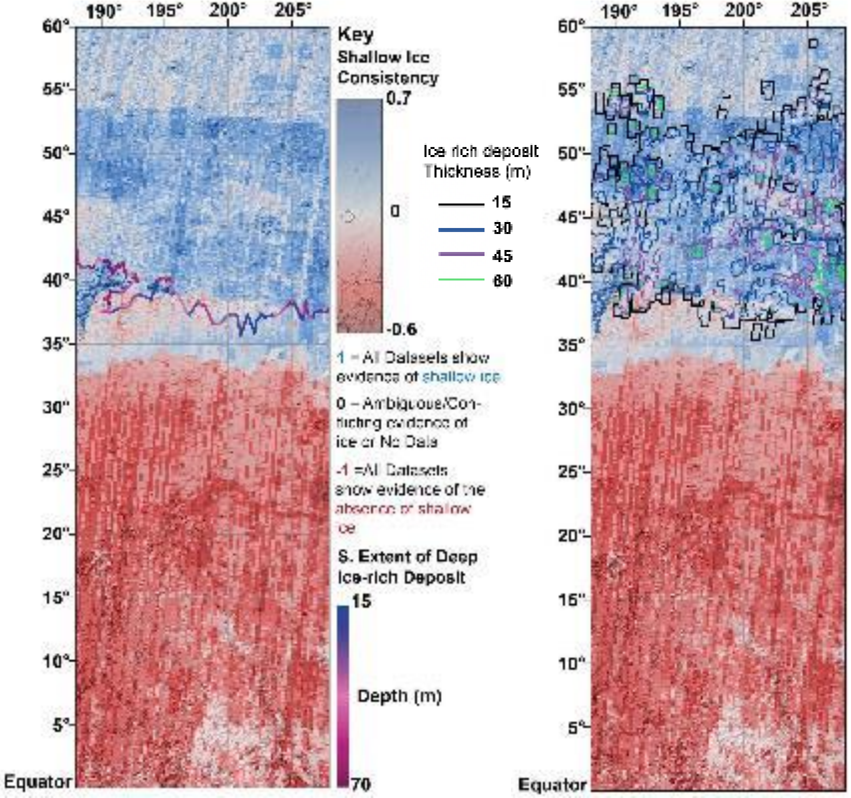
SHARAD: Depth of Potential Icy Deposit

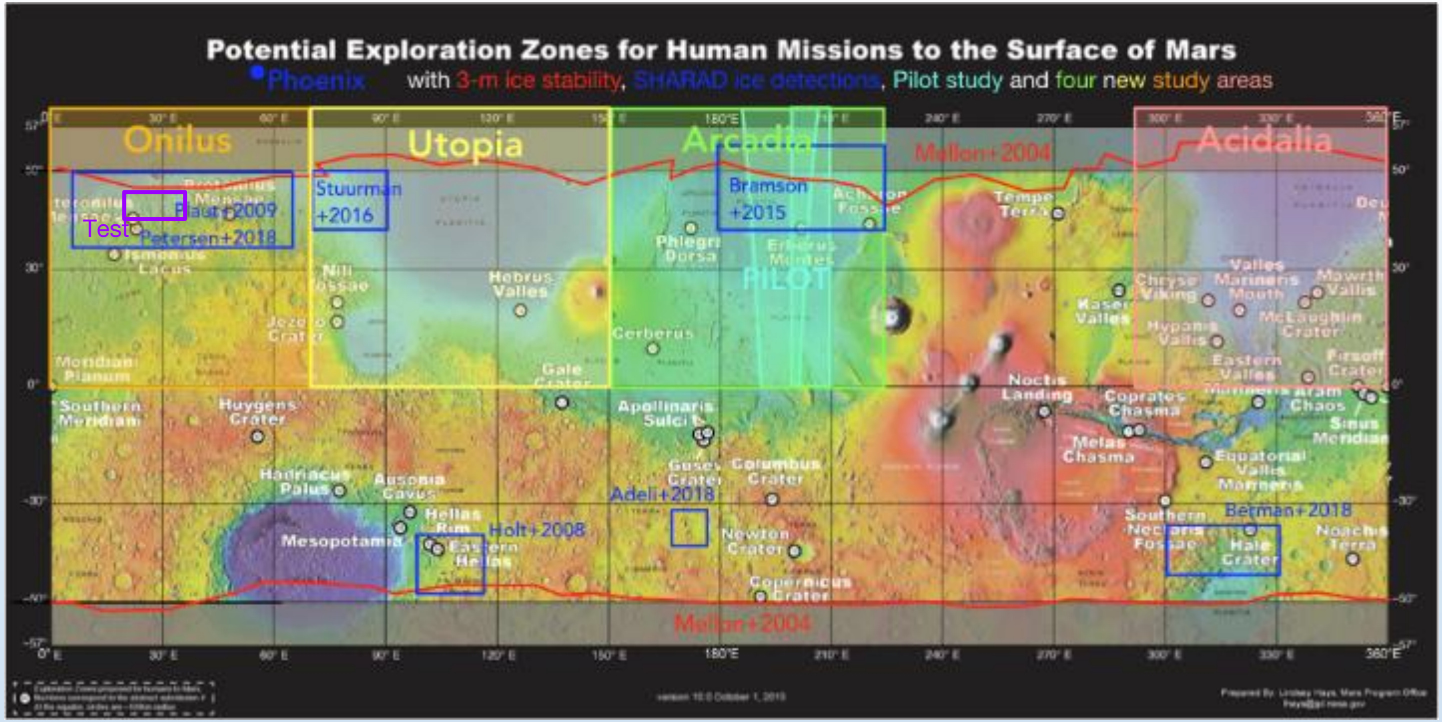


Consistency: Shallow + Deep



Study Swaths

Four main northern hemisphere regions:



Final products will provide further constraints to facilitate human landing site studies.

Consistency: Deuteronilus

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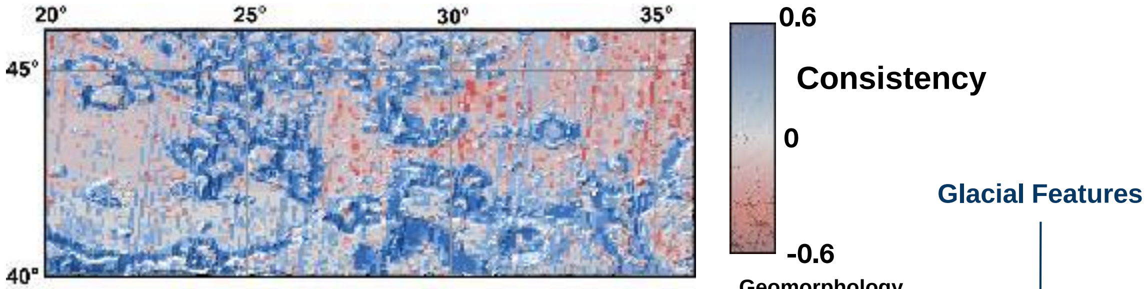
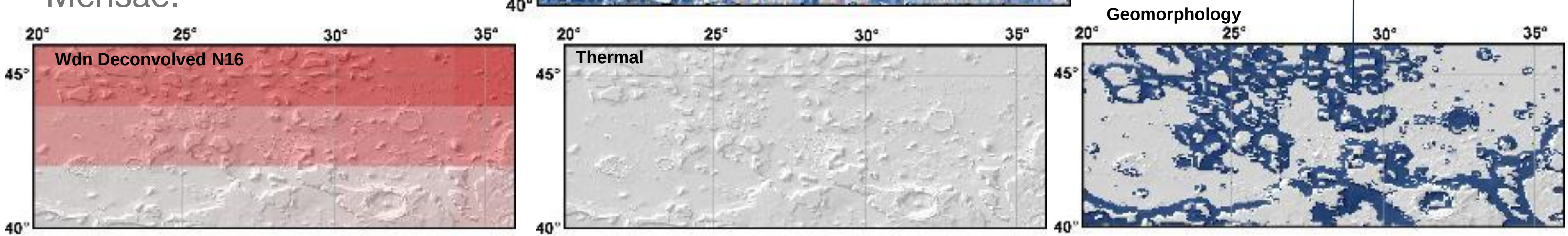
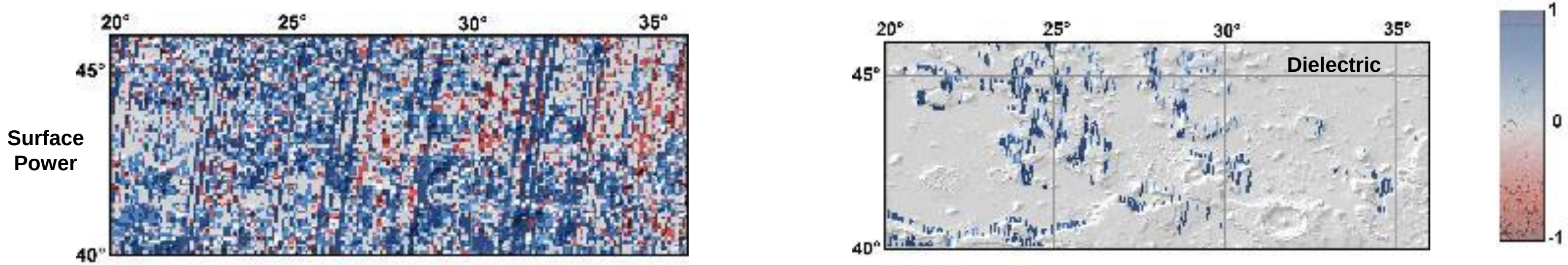
We carried out a preliminary test of consistency mapping in a subset of Deuteronilus Mensae.







Study Products

https://swim.psi.edu

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Primary products for each swath

- Ice consistency maps
  From neutron & thermal data, morphological features, radar surface reflectors, subsurface dielectric values, and composites from all data
- Top of ice depth maps
  From thermal data & SHARAD surface returns
- Base of ice depth maps
  From SHARAD subsurface reflectors
- Ice concentration maps
  From SHARAD+DTM permittivity estimates

In addition, we will provide supplemental products associated with each study element & swath

Pilot study products now available!

Spreading the Word/Results to the Community!